MONTHLY WEATHER REVIEW.

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The MONTHLY WEATHER REVIEW is based on data from about 3500 land stations and many ocean reports from vessels taking the international simultaneous observation at Greenwich noon.

Special acknowledgment is made of the data furnished by the kindness of cooperative observers, and by Prof. R. F. Stupart, Director of the Meteorological Service of the Dominion of Canada; Señor Manuel E. Pastrana, Director of the Central Meteorological and Magnetic Observatory of Mexico; Camilo A. Gonzales, Director-General of Mexican Telegraphs; Capt I. S. Kimball, General Superintendent of the United States Life-Saving Service; Commandant Francisco S. Chaves, Director of the Meteorological Service of the Azores, Ponta Delgada, St. Michaels, Azores; W. N. Shaw, Esq., Secretary, Meteorological Office, London; H. H. Cousins, Chemist, in charge of the Jamaica Weather Office; Señor Anastasio Alfaro, Director of the National Observatory, San José, Costa Rica; Rev. L. Gangoiti, Director of the Meteorological Observatory of Belen College, Havana, Cuba.

As far as practicable the time of the seventy-fifth meridian, which is exactly five hours behind Greenwich time, is used in the text of the MONTHLY WEATHER REVIEW.

Barometric pressures, both at land stations and on ocean vessels, whether station pressures or sea-level pressures, are reduced, or assumed to be reduced, to standard gravity, as well as corrected for all instrumental peculiarities, so that they express pressure in the standard international system of measures, namely, by the height of an equivalent column of mercury at 32° Fahrenheit, under the standard force, i. e., apparent gravity at sea level and latitude 45°.

SPECIAL ARTICLES, NOTES, AND EXTRACTS.

STUDIES ON THE THERMODYNAMICS OF THE ATMOSPHERE.

By Prof. FRANK H. BIGELOW.

VI.—THE WATERSPOUT SEEN OFF COTTAGE CITY, MASS., IN VINEYARD SOUND, ON AUGUST 19, 1896.[1]

THE SOURCES OF THE DATA USED IN THE DISCUSSION.

This waterspout has an especial scientific interest to meteorologists because it was seen under circumstances remarkably advantageous for making observations and photographs, from which it is possible to compute, with much accuracy, the dimensions of the tube, and thus facilitate the application of the mathematical theory of vortices.

A series of papers and letters from various persons who saw the phenomenon, and a very complete set of photographs, were secured at the time by the Editor, which he has courteously placed at my disposal for incorporation in this paper, and they will be found inserted in the following pages. I have myself been familiar with that part of the Massachusetts coast, and have therefore been interested to study the facts as thoroughly as possible as preliminary to the discussion of this type of vortex motion. I accordingly visited Cottage City the following September, and was conducted by Mr. Chamberlain to the spot where he placed his camera for making his photographs. There I made a sufficiently accurate survey of the linear distances between that spot and the telegraph poles shown in his pictures to determine the scale of distances for all objects. Furthermore, by collecting and collating all the data relative to the positions of the waterspout and the schooner seen in the several photographs, I am able to plot them on the Coast and Geodetic Survey Chart No. 112, in such a way as to reconcile nearly all of the statements made regarding the distances and progress of the two objects, respectively. The photographs taken from such distances as Vineyard Haven and Falmouth Heights give an excellent view of the whole cumulonimbus cloud from which the tube descended, and its connection with the thunderstorm which preceded it. All these data will enable us to discuss the subject of tornado and waterspout formation with considerable fulness, and with the conviction that confidence may be placed in the comparison of the observations and computations. There is every reason to believe that the photographs are perfectly genuine, and free from touches to add to their artistic beauty at the expense of scientific accuracy. Certain preliminary computations were made in 1897, the result of which was published in the International Cloud Report, page 633, Report of the Chief of the Weather Bureau 1898–99, Volume II; this was republished in the MONTHLY WEATHER REVIEW.[2] My purpose then was to illustrate the application of certain formulæ, and it was my intention at that time to complete the study as soon as my other duties permitted. In these present papers I shall begin with the descriptive accounts of the waterspout, then pass to a discussion of the facts as shown by these reports and the photographs, and finally consider the dynamic motions and the thermodynamic conditions present in the atmosphere near Cottage City on that occasion.

LETTERS AND REPORTS OF OBSERVERS.

The following letters, reports, and observations have been furnished by the several authors. It will be instructive to refer to fig. 25 while reading these papers.

(A) EXTRACT FROM THE DAILY JOURNAL OF U. S. WEATHER BUREAU STATION, VINEYARD HAVEN, MASS., W. W. NEIFERT, OBSERVER.

August 19, 1896.—Partly cloudy weather during the morning, with gentle northerly wind. Three magnificent waterspouts were observed in Vineyard Sound to-day, in northerly direction from station, about ten miles distant. During the entire afternoon the weather was partly cloudy and sultry, with great masses of cumulus clouds in the north and northeast. *At 12:45 the first display was observed.* At first a long spiral column seemed to fall from the clouds, about the thickness of a man's body, but this gradually increased in size as the cloud lowered, and when it reached the water it was as thick as a large sized cask, and changed in color from a rich gray to a black, and assumed a funnel shape at the base of the clouds. The cloud seemed of a yeasty white where the column came in contact with it, and looked as though the water was hauled up to it. The area of contact appeared small. The spout was very straight and almost perpendicular, kicking up a great sea as it traveled. When it disappeared it began to do so at the base and rapidly reached the top, having the appearance of clouds, and finally cleared away, like steam from an engine, at 12:58 p. m., leaving a clear sky for a background and the original clouds above. *At 1 p. m. it formed the second time*, which was really the most interesting spectacle of all. From a mass of inky clouds it reached down, finger-like, to almost the ocean's surface. Below it the water was stirred to an angry whirlpool, the foam reaching up perhaps a hundred feet. It appeared as though great volumes of water were traveling up to the cloud by an endless screw, when suddenly, at 1:18 p. m., the long arm disappeared in a manner similar to the first. *At 1:20 it formed for a*

[1] No. V of the series ("The Horizontal Convection in Cyclones") will follow later.

[2] May, 1902. Vol. XXX, pp. 257, 258.

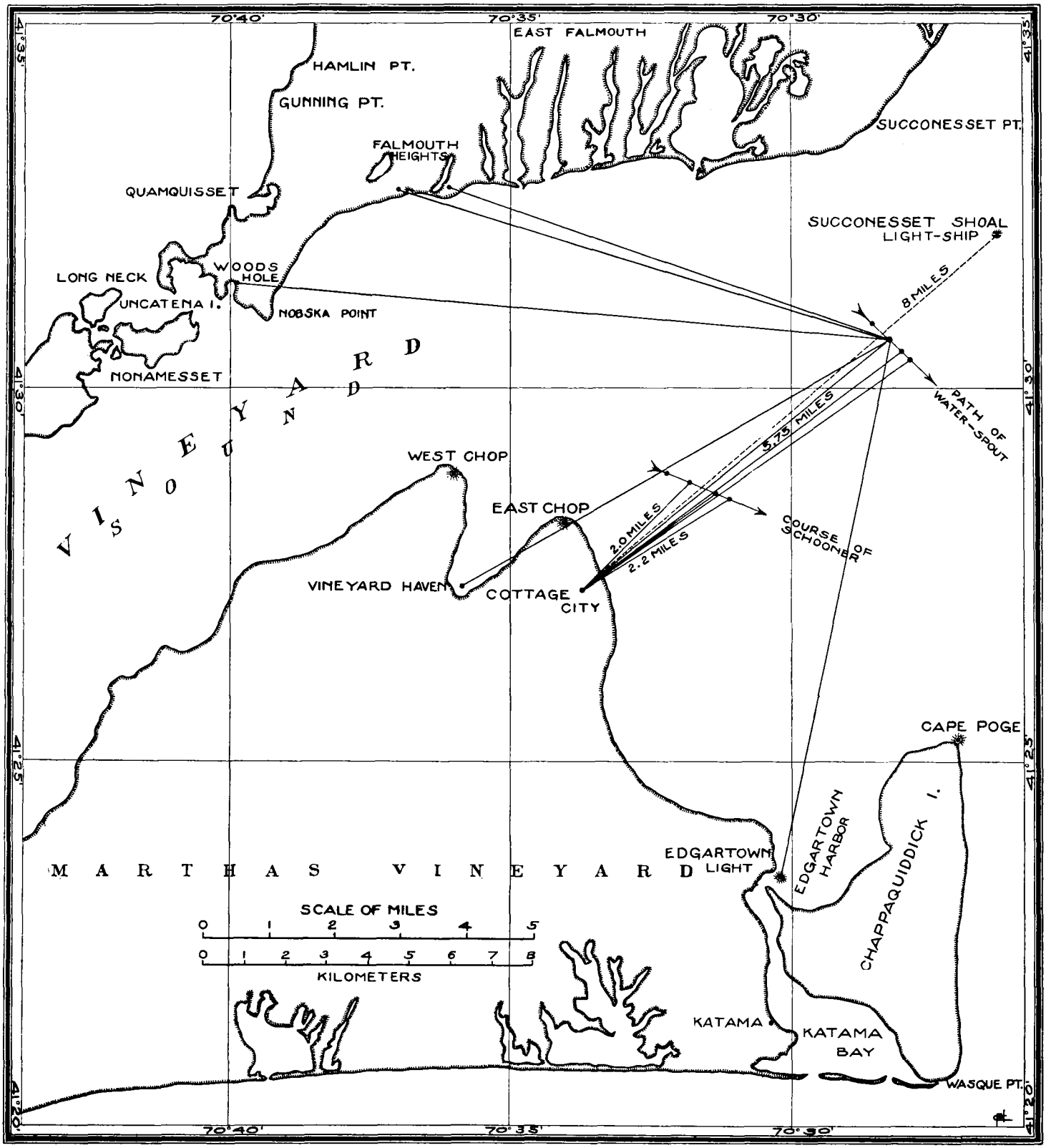

FIG. 25.—Location of waterspout seen in Vineyard Sound, August 19, 1896. (Reduced from United States Coast and Geodetic Survey chart No. 112.)

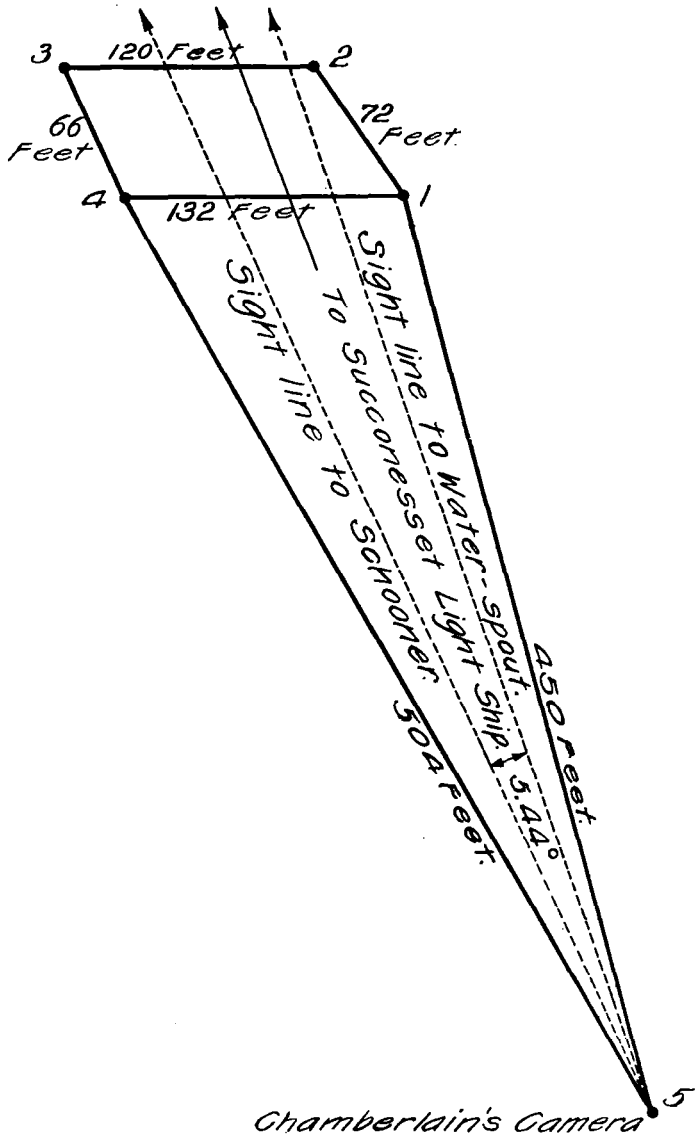

FIG. 26.—Diagram of the survey between site of Chamberlain's camera and four telegraph poles shown in his photograph, 2d A (fig. 27).

third time and scarcely reached the water, but had a decided funnel shape, lasting about five minutes, when it slowly withdrew into the blackness above and the surface of the ocean became quiet. There was a sprinkle of rain from 12:54 to 1 p. m., amounting to a trace. During the display the wind at the station was six miles per hour from the northwest; temperature 72°, with a fall to 56.5° during the thunderstorm which followed, passing over the station from northwest to south. Thunder was first heard at 1:45 p. m.; loudest at 3:04 p. m.; last at 3:45 p. m. Heavy downpour of rain from 3:04 to 3:15 p. m., then continued light rain until 3:30 p. m. Amount, 0.38 inch. The summer residents were stricken with fear at the approach of the dark clouds over the sound, and viewed the waterspout with mingled feelings of awe and interest. It was a sight long to be remembered, and when the weather cleared, about 4 p. m., each expressed himself as being most fortunate in having escaped some dreadful calamity. No noise was heard here, but the schooner-yacht *Avalon* of Boston was very near the spout and those on this vessel reported plainly hearing the noise and the wind blowing around the vortex with wonderful rapidity; to them the spout appeared to be one hundred feet in diameter. The three spouts moved gracefully to the eastward. This is the first display of this phenomenon witnessed here for 27 years. Mariners here who have circled the globe a number of times, and have seen dozens of waterspouts, declare it to be the most perfect specimen they ever observed.

(B) LETTER FROM MR. NEIFERT TO MR. A. J. HENRY. DATED VINEYARD HAVEN, MASS., DECEMBER 19, 1896.

When I first saw the waterspout it was in the vicinity of Black Buoy No. 13, on the east end of L'Hommedieu Shoal. Can not say now exactly, but in that general direction. Could just see base off East Chop. When the photographic view was taken here it was about where the red dots surround sounding marked 8¾. It appeared nearer then, but I presume this was caused by its base being hidden by the "highlands". The view from here was taken from on board of a yacht which lay at the red dot between the two wharfs or the head of the harbor under the figure 3 of the sounding marked 13.[3] It may not be so far, but that is as I remembered it. There was so much confusion, women and children crying, that I was not very observant until it was over.

Coolidge was just north of the head of the wharf in Cottage City, and the "spout" was in an east-northeast direction from him. His views were made from the same position, and only time enough elapsed between them to change the plates.

(C) EXTRACT FROM THE DAILY JOURNAL OF THE U. S. WEATHER BUREAU STATION, NANTUCKET, MASS., MAX WAGNER, OBSERVER.

August 19, 1896.—Clear weather all day, except in the afternoon, when light rain began at 2:40 p. m. and ended at 4 p. m. Total amount 0.03 inch. Cooler, with rising barometer. Mr. Wagner went to Cottage City in the morning to check up; from there he observed the big waterspout that formed in Nantucket Sound. An ordinary thundershower was passing across the sound when, about 12:40 p. m., a huge black tongue shot down from an alto-cumulus cloud that floated a half mile high at the northern edge of the shower, and after rising and falling a number of times, finally joined a shorter tongue that seemed to leap out of the water to meet it. Twice the column parted for a moment, but joined again instantly. There was no apparent motion of the waterspout forward, and the phenomenon lasted for half an hour. It was pronounced by many sea captains who witnessed it the finest waterspout they had ever seen. No damage was done by the spout, but a small catboat which arrived at night reported being becalmed near the spout, the crew being badly scared.

(D) EXTRACT FROM THE DAILY JOURNAL, U. S. WEATHER BUREAU STATION, WOODS HOLE, MASS., J. D. BLAGDEN, OBSERVER.

August 19, 1896.—Three waterspouts were reported in the Vineyard Sound and one in Buzzards Bay between 12:35 and 2 p. m. One waterspout was photographed with excellent results.

(E) COPY OF A CIRCULAR ACCOMPANYING COPYRIGHT PHOTOGRAPHS. BY J. N. CHAMBERLAIN, OF COTTAGE CITY, MASS.

About 12:45 noon, August 19, 1896, we were startled by the cry of "A waterspout!" and with our assistants started with the camera to the park in front of Doctor Tucker's residence, where we could see, a little north of the direction of Nantucket, very dark and angry clouds, out of which a funnel-shaped cloud of various colors, with a pointed streak, issued downward until it touched the water. We obtained two photographs of this, showing a slight difference. [One of these views is reproduced as fig. 27.] After about twelve minutes it gradually and completely vanished. Very soon a second one appeared, more curved than the first, with a long sharp streak from the same clouds and slowly extending downwards to a point about one hundred feet from the surface of the ocean. In a few moments this changed to a smaller streak with a different curve bending to the south, while the former bent to the north. Both of these we photographed [figs. 34, 35]. The height of this, which Professor Dwight of Vassar College says was a genuine waterspout, was about a mile. The cloud-burst disturbed the water in the sound for several hundred yards until it looked like a boiling pool. We could trace through the camera the spiral motion of the water as it was drawn into the clouds, every moment augmenting their portentous darkness. The cloud from above and the spray from below were drawn together by suction, and condensed torrents of water poured down a few hours later, which was found by persons in different places on the island to be salt, and proves that it was carried up to a height and scattered round as solid bodies are by tornadoes on land. The Greeks applied the term "prester" to the waterspout, which signifies a fiery fluid, its appearance being generally accompanied with flashes of lightning and a sulphurous smell showing the activity of the electrical principle in the air.

(F) A REPORT TO THE EDITOR BY PROF. WM. B. DWIGHT, VASSAR COLLEGE, POUGHKEEPSIE, N. Y. DATED MARCH 22, 1897.

I now inclose such statements as I am able to make without the few memoranda, noted on the spot and since lost, of the waterspout of last summer at Cottage City.

The basis of my estimates of the height of the waterspout is rather hypothetical, but I submit them for what they may be worth. I have endeavored to assume my units of measurement so as to be *below* rather than *above* the fact, in order that the estimate might not seem to be made in a spirit of exaggeration. Thus, I am inclined to think that the distance of the schooner, in the photographs, from the shore is nearer three than four miles, which would make the spout higher than my estimate. One reason for my thinking so is that there is a buoy, the three-mile buoy, so called, not far from the position of the schooner and in front of her, about three miles from the shore and marking the channel. She was

[3] On chart not reproduced.—EDITOR.

likely aiming for that buoy and then would not be very far from it. On the other hand, the state of the wind might lead her to go as much as half a mile or more outside (to the east) of it. I presume that the opinion of the seamen at Cottage City on the distance of the schooner could be easily obtained and would be of value. I think that I obtained such an opinion, but it is lost with my other memoranda and I can not now recall it. I have searched for the three-mile buoy in the photographs, but it is a very small object and I cannot identify it.

Some statements as to the waterspout in Nantucket Sound (sometimes called Vineyard Sound) easterly from Cottage City, Marthas Vineyard, Mass., at noon of August 19, 1896, made from personal observations by William B. Dwight, of Vassar College, Poughkeepsie, N. Y. (resident in the summer at Cottage City).

My summer cottage is situated close to the beach at Cottage City, with unobstructed view of the ocean. I was standing upon my private wharf, nearly in front of the cottage, when the waterspout of August 19, 1896, began; I saw it at the outset and was among the first to call general attention to it in our part of the town. I watched it closely, with the assistance of a good field-glass till the close of the phenomenon, but I had no proper instrument at my command for taking the altitude.

Excellent photographs were taken by Mr. Coolidge and Mr. Chamberlain. I am able to testify to their general correctness as corresponding with personal observation. Mr. Coolidge's are most artistic views of the whole scene and scenery. Three of Mr. Chamberlain's present with accuracy three consecutive views of the waterspout in its phases, changes, and progress taken from one and the same spot. They were taken with total disregard of the foreground and the sole aim of getting the best views of the spout itself. These facts give these three views a marked scientific value, and these photographs will repay a careful scientific study.

Like all of the three phenomena of this kind which I have personally observed (and this is the second which I have seen from Cottage City), the funnel of the tornado is constantly changing its form, length, and other dimensions; and occasionally, or at intervals, it may entirely disappear in its cloud, only to reappear again in full force. This one had several such successive appearances with intervals of total disappearance. Hence the photographer, the newspapers, and the spectators generally described the appearance of several waterspouts on this occasion. I consider this an unscientific and unfortunate mode of describing this phenomenon, chiefly for these two reasons.

1. There was only one great but entirely distinct and individual cloud concerned in the phenomenon from beginning to end, and in fact only one particular spot in that cloud. This not only follows from my own observation but is demonstrable from a study of Chamberlain's three photographs, as I propose later to show. This cloud and its point of vortex movement sustained constantly throughout the waterspout phenomenon, three quarters of an hour (or more), the same relation to the furious squall of lightning, thunder, rain, and hail, going on about a mile to the southeast of the waterspout, i. e., a mile from the thunderstorm to the edge of the waterspout. This squall is clearly visible in Chamberlain's first photograph of the three mentioned.

2. From the point mentioned in the tornado cloud, (as I will designate it in distinction from the squall cloud), a waterspout funnel would descend to the ocean, and move along its surface in an easterly direction, with its cloud; after a while it would thin out, or break into pieces, and nearly or quite disappear. For the most part, however, the location of its minimized force in the cloud remained marked clearly by a downward bulging of that part of the cloud, with indications often of rotary movement at the spot. Once, however, the spot where this tendency to vortex motion still existed was for a few minutes lost to view; but soon the vortex movement visibly returned somewhere along the line between the cloud and the ocean, from the point of the cloud which was affected. It generally appeared first at the cloud, but once the vortex movement at the ocean's surface was practically simultaneous with that at the cloud; then another column or spout was completely formed, but as the cloud had been moving eastward during the interval, the spout would of course be seen in a position somewhat to the eastward of its former place; and so this disappearance and reappearance was several times repeated. Those of the more intelligent observers who insist that there were "several waterspouts" on this occasion base their statement on these two arguments: (1), that there were successive spouts seen; (2), that no two of the spouts were in the same place.

On the contrary, I hold that my preceding remarks, and the further facts to which I shall call attention later, show that this was the same phenomenon, that is, the same center of vortex action, throughout, and that its different appearances were not different waterspouts, but simply different and varying phases of one and the same phenomenon. As to the second point, the difference in position, I contend that the differences in position were only those which a waterspout drawing itself up into its cloud, and then coming down again, must necessarily take in consequence of the constant southeastward progress of the storm. It could not come down in the same place any more than a circus rider can when he leaps up from the back of a running horse and comes down again several feet ahead of his former position. The successive phases of this waterspout, in their positions, follow strictly the eastward movement of the tornado cloud, and inspection of the three photographs of Chamberlain's set shows that a line between the first and last phase of his three would pass through the position of the intervening one.

This may seem a matter of little consequence in terminology; but it is of importance in view of the fact that the expressions "two waterspouts", "several waterspouts", etc., are positively needed for cases where two or more entirely independent phenomena of the kind are in sight at the same time, or nearly so; as when a friend of mine once saw eleven waterspouts on the ocean simultaneously.

I will now give a brief description of the successive phases of the waterspout as I observed it.

I was standing on my own private boat wharf, which is on the seashore at the extreme southeast point of Cottage City, one-half mile exactly south of the "Oak Bluffs" or main wharf, the wharf shown in Coolidge's photograph, No. 7933, fig. 28, a little after half-past twelve. In the excitement of the occurrence I failed to note the exact time An exclamation from a friend standing near me drew my attention to the waterspout, which had just formed in the rear of a black thundersquall which we had been watching to the southeast, the wind being from the northwest. The waterspout being a mile or more in the rear of the squall and separated from it by a clear interval, was a little north of east from my position of observation; it appeared to be somewhat nearer than the Succonesset light-ship (on Succonesset Shoals), which is nine (9) miles easterly from Cottage City; at the same time it was evidently nearly as far. I had several interviews subsequently with captains of the local fishing catboats, all men of lifelong experience as coasters, with reference to the probable distance of the spout. They all estimated it as from eight to ten miles away; no one gave a less estimate than eight miles. All but one of the captains had seen it only from Cottage City. One captain, however, told me that he was sailing to Cottage City from Cape Poge, a point seven miles to the southeast of Cottage City, and saw the waterspout when he was off that cape, and that it was certainly nearer to Cottage City than the Succonesset light-ship (which from his position would be much in the same direction); he said it was, in his judgment, about one mile nearer to Cottage City than the light-ship; this is excellent testimony on this point, and I think we may safely set the distance of the waterspout from the Cottage City wharf as having been just about eight miles.

At this first phase the waterspout was very tall and very thin; in fact it presented very much the same appearance as in No. 3 of Chamberlain's set, fig. 35, though in a much more northwesterly position; at its base was a spherical mound of up-whirling water and spray several times wider than the main portion of the column, a white dot of foaming water appearing at the center of this mound at the ocean's surface; the column was sinuous and moderately expanded as it joined the cloud. The tornado cloud had a broad, flat, angry looking under surface, little tufts of mist or rain descending from it here and there; it extended at least a mile to the east and southeast, joining the thundersquall in the latter course. Toward the north and west it was much less extensive, and in fact more than one-half of the sky over Cottage City was in bright sunlight. At times it appeared as if streaks of rain were descending from the tornado cloud to the ocean all around the waterspout in all its successive phases.

This *first phase is not shown in any* of the professional photographs, though probably some amateur's camera may have caught it. Comparatively few persons saw it, that is only those who happened to be at the beach; the morning bathing hour was mostly over; the professional photographers were in their offices inland; it took time to get word to them and for them to bring out their instruments and get them placed in good positions. Meanwhile, this first phase faded away, and that one of the views of the photographers which is generally called the "first waterspout" is not at all the first, but the *second* phase, and a much larger and grander one. The second phase, which appeared at about a quarter to one o'clock, was by far the grandest one of all. It is the "first" one of the photographers, the one shown by Mr. Coolidge's photograph numbered 7933, fig. 28. It began by the formation of a broad funnel on the under side of the tornado cloud, which then became a very broad black tube. This rapidly stretched down to the ocean, where it raised a large mound of whirling, foaming, rising water at the center, and of spray around its margin. The white center of upward rushing water was usually clearly visible to the naked eye, and through a field glass was very marked. At other times it was completely obscured by the surrounding mist and spray, and was never relatively large to the view, because so thoroughly enveloped. * * * There was no white water visible at any time in the tube proper, above the mound. This phase lasted probably about fifteen minutes, during which it varied in form from a slender, even cylinder, to a massive, imposing conical tube, as it swept on slowly and majestically to the southeast.

From this phase we are enabled, through Mr. Chamberlain's valuable set of photographs, to trace the forward progress of the tornado cloud visibly, and the relations of this and the succeeding phase to each other, since these three views were taken by the same camera and lens, and from exactly the same point. (I have established this point, as it is easy for any one to do, on the spot, by taking a position on the west margin of the main portion of the Ocean Park adjoining the Oak Bluffs dock, where the relative positions of the telegraph poles, and their several arms and wires can be made to coincide exactly with their relative posi-

tions in the photographs. It will be noted that these positions are exactly the same in the three views, though in the last one the camera was revolved more to the southeast than in the others. This point of observation proves to have been at the center of the convex western edge of the main body of the park, just east of the carriage road which extends in a curve from one point of the Sea View avenue to another point of the same avenue around the west edge of this main portion of the park. It is called Ocean avenue. The point where the camera stood is just east of Ocean avenue, where a straight line running through the east end of Fisk avenue would strike it.)

Now, in examining Chamberlain's first view, fig. 27, where the grandest phase is seen, the waterspout is shown a little north of the two central telegraph posts of the view, while a schooner is seen sailing southeast about three or four miles from the shore, some little distance to the north of the waterspout. Also, a little northerly of the waterspout, about a third of the apparent distance (in the view) between it and the schooner, the masts of a vessel at anchor appear on the horizon. This is apparently the Succonesset light-ship, nine miles away. It is certainly about the position of that light-ship, and resembles closely its familiar appearance, as seen from Cottage City. This would seem to locate exactly the direction of this phase of the phenomenon from Cottage City. As my charts of Nantucket Sound (or Vineyard Sound) are at Cottage City, and my notes made on the spot are lost, I can not at this time state the bearing of the light-ship from the point mentioned as the position of Chamberlain's camera; but it can easily be settled by reference to such a chart.

Mr. Coolidge's photograph No. 7934, fig. 32, seems to show a later form of this phase, the column having grown thicker and more evenly conical since Chamberlain's first and earlier view was taken. This appears from the fact that the schooner is now much nearer to the line of direction of the waterspout, in which direction she was sailing faster, apparently, than the spout was moving in the same direction. It is true that Coolidge's standpoint was evidently to the north of Chamberlain's, being near the steamboat dock, and quite near the shore, while Chamberlain's position was about five hundred feet from the shore. But when all allowances for difference in position have been made, there seems to be still quite a margin which can only be explained by the fact that the vessel had actually had time to sail some distance southeasterly.

When this grandest phase disappeared the spout was for a few minutes totally absorbed into the cloud. Then, while I was closely watching it for further developments, a whirling funnel began to bulge down from the tornado cloud, while at the same moment, and before the funnel was more than a mere projecting knob on the cloud, the water on the surface of the sound just beneath began to boil furiously, and to rise up in a whirling mound, indicating a line of vortex motion already established the entire distance between the cloud and the sea. Next, while the upper tube began to extend downward, a central portion of the tube was formed, entirely independent of the upper and lower portions, as clear spaces existed between.

This is finely shown in Chamberlain's second photograph, fig. 34, where the three portions are distinctly seen before their union. Many persons on seeing his three views take the one which shows the waterspout as a very slim tortuous tube, fig. 35, as the first exhibition of a waterspout, of which the one in three portions is but the breaking up phase. That this is not the case is indicated by my own most positive observation of the triple formation of the spout, to which I called the attention of bystanders at the time. But, further, the photographs themselves prove the incorrectness of that idea; for it will be noted that in the view of the spout having the triple structure, fig. 34, the column has just passed from its second phase, where it appeared a little to the north of the pair of central telegraph posts, to a position a little to the south of the more northerly of these posts, while the schooner has passed to a central position between them. In the other view, fig. 35, the column has come near to the more southerly of the posts, while the schooner has passed considerably to the south of both, and has been closely approached by a tug towing three barges, which was only just coming into view in the other photograph.

I need only to remark further, therefore, in this connection, that the third of Chamberlain's set of photographs, fig. 35, represents the completed form of the waterspout shown in the second view, and the third and last actual phase of the entire phenomenon. As this phase disappeared at about 1:25 p. m., the entire occurrence covered a little over three-quarters of an hour.

If one were disposed to form some estimate of the rate of progress of the waterspout, from that of the schooner, the following points would deserve consideration:

1. Though the wind was violent in the vicinity of the squall, there was but a moderate wind on the shore and in the vicinity of the schooner. This is not a matter of my recollection alone, for the photographs show it; the sea near the shore is little disturbed, while the schooner carries all sail except topsails, and has no reefs. If we may estimate the probable length of her hull as 75 feet (a moderate estimate), she must have gone somewhat over half a mile during three-quarters of an hour. Her course being somewhat oblique to the line of vision, and veering away from the observer, is really longer than it measures on the photograph. The tide runs with great force, and may have worked against the schooner.

2. The waterspout was certainly twice as far away as the schooner. Supposing, as is very likely from evidence elsewhere offered, that it was just about twice as far, and moving, as appears to have been the case, in the same course, the tornado cloud and the waterspout must have progressed considerably less than twice as fast as the schooner, since the latter, starting from a spot considerably to the north of the spout passed to the south of it.

Toward the close of this phenomenon the eastern half of the sky became quite bl . k with clouds, while the entire western half, where the Cottage City observers were, was brilliant with sunlight, which at this hour glanced easterly beneath the blackness. The chromatic effects were of an indescribably rare and beautiful kind. The surface of the sound for several miles out was lighted up with weird hues of bright blue, green, yellow, and gray, in patches, according to the nature of the variable weedy and sandy bottom, greatly intensified by the solemn, black storm clouds and waterspout overhead. Thousands of spectators, crowding the beach, gazed on the sight with mingled admiration and awe.

I append some estimates of the probable dimensions of the waterspout founded on its apparent distance, as ascertained by investigation, and upon measurements of the photographs, using as a unit the hull of the schooner in view, estimated as 75 feet long and four miles from shore. I am inclined to think that the schooner's distance was nearer three than four miles, and that the estimates should be increased proportionally. By my estimate the waterspout would have an altitude of about half a mile.

The conditions of the photographs of Chamberlain's series might afford another basis for an estimate.

By ascertaining the distance from the spot where the camera stood to the higher one of the central pair of telegraph posts (as the other stands on lower ground), which distance is not far from 500 feet, and the height of the telegraph post, and assuming the probable distance of the waterspout as eight miles, triangles could be constructed from which the height might be calculated, provided that the telegraph posts were not so near to the camera as to be disproportionately magnified. I suppose corrections might be applied for such irregularity if the power of the lens were known.

Rough estimates as to dimensions of the waterspout seen from Cottage City, Mass., August 19, 1896.

(1) Estimates founded on photograph No. 7934, fig. 32, taken by Coolidge, and based on the supposition that the waterspout was eight miles from Cottage City, and that the schooner visible to the north of it is 75 feet long and four miles from Cottage City. In this photograph, the schooner's hull (not including the bowsprit), estimated at 75 feet, measures one-tenth inch. The waterspout being twice as far distant should therefore measure 150 feet for every one-tenth inch of dimension. Some correction should be made, in strict calculation, for the tendency of the camera to magnify near objects more than distant ones; but this is comparatively slight for two objects both of which are distant, and may be disregarded in a rough estimate.

Using this unit of measurement, 1-10 inch on the photograph corresponds to 75 feet at the schooner, or 150 feet at the spout:

	Feet.
Height from surface of ocean to lower edge of cloud (= 1.917 inches)	2874
Mound of spray at base of the spout:	
Height	600
Breadth	750
Breadth of the mass of foaming water in this mound	150
Tube or funnel proper, above the base mound:	
Breadth (diameter) just above the mound	150
Breadth about the middle	300
Breadth at extreme top where it joins the cloud	600

(2) Estimates founded on a photograph by Chamberlain, fig. 27, and called by him the "first" waterspout. It shows the spout of larger size and grander appearance than the later views. These estimates are based on the assumed length of the schooner in sight, and its distance, assisted by known facts as to the position of the ship channel, and on the supposed distance of the waterspout, judging from reports of captains of fishing boats who got its range. This is really the second and not the first stage or appearance of the spout, as witnessed by myself from its very beginning.

In this photograph the hull of the schooner (75 feet) measures 13-100 of an inch. Its estimated and probable distance is not over four miles, that of the waterspout eight miles. Hence the unit of measurement, 13-100 inch, would cover 150 feet at the waterspout. The dimensions would then be as follows:

	Feet.
Height from ocean to cloud	2600
Height of basal mound of spray	300
Width (diameter) of basal mound of spray	600
Tube proper:	
Width at lowest point	150
Width at middle point	100
Width at top	375

Remarks.—This photograph represents, as I can testify from personal

observation, the same spout, or phase of the spout, as Coolidge's No. 7934; but at a different minute of its existence, since the form is considerably different. The spout was changing constantly in length and width within certain limits, but was throughout the largest of the phases. The difference in the apparent length of the schooner's hull from that in Coolidge's photograph is due probably to a stronger lens.

(G) LETTER OF E. B. HANES, TO THE EDITOR. DATED COTTAGE CITY, MASS., OCTOBER 26, 1896.

Your letter of October 20 is at hand. I am sorry to say that I do not know of any scientific observations of the waterspout seen in Vineyard Sound, August 19. I had an excellent view of it throughout its entire duration, a portion of the time through a six-inch astronomical telescope. It occurred August 19, 1896, at about 1 o'clock p. m. It had been a calm summer day, with but few clouds, temperature about 70°, with but little variation before and after the phenomenon. It has been stated that there were two or three waterspouts; this, I think, is hardly correct, as no one saw more than one at the same time, the so-called different ones being different forms or *reformations* of the same spout. Its beginning was, from my point of view at Cottage City, about six miles distant, in a line toward Cotuit; its ending, about eight miles, in a line toward Hyannis. It had a steady progressive movement and was inclined forward in the direction of advance. I estimate its forward movement at about eight miles in the thirty-five minutes it continued. During the time of the waterspout, showers, with lightning, could be seen preceding and following it in its course; about an hour afterward Cottage City was visited by a tempestuous downpour of rain. Through my telescope the column seemed to be surrounded by a dense vapor, which radiated like smoke from its edges, and, condensing, fell in torrents of rain for a distance in either direction about equal to the diameter of the column. At first the edges of the column were quite well defined, later it grew much larger in diameter and more diffuse, its height remaining the same throughout. While I could not penetrate with my telescope the enveloping mist so as to see if there was a solid or tubular mass of water either ascending or descending the inner part of the spout, nor detect a whirling or spiral movement, yet the funnel shape at the top and general appearance indicated that character. Based upon estimates of the most careful observers, its probable size was from 100 to 300 feet in diameter at different periods, and 4000 to 5000 feet high. Where the column joined the sea there was a great churning and splashing of the water, which extended as white mist for 200, or more, feet upward and outward; this was more pronounced toward the last. When the spout finally disappeared it grew slender and broke about midway of its height, the lower portion dropping into the sea and the upper dissipating into the cloud.

(H) EXTRACT FROM THE REPORT OF THE CLIMATE AND CROP SERVICE, NEW ENGLAND SECTION, AUGUST, 1896, BY J. WARREN SMITH, SECTION DIRECTOR.

On August 19 three well-defined and magnificent waterspouts were observed in Vineyard Sound, between the eastern edge of Marthas Vineyard and the mainland, about off Succonesset Shoal.

Mr. W. W. Neifert, the Weather Bureau observer at Vineyard Haven, writes: "During the entire forenoon the weather was partly cloudy and sultry, with great masses of cumulus clouds in the north and northeast". [The remainder of this quotation is practically identical with (A) above.—EDITOR.]

We have reports of the phenomenon from Mr. E. H. Garrett, who observed it from the coast between Hyannis and Oysterville; from John B. Garrett, who saw it from Falmouth Heights, and from Dr. S. W. Abbott, Secretary of the State Board of Health, who was in West Falmouth Harbor at the time.

Mr. E. H. Garrett says: "We were out on the beach and saw an odd looking cloud in the sky. It seemed to have a curious appendage at first, which one of the party described as looking like 'an icicle.' We turned to go home, when one of the group looking back saw the 'icicle' changing, and we all watched. It grew larger, then looked like a long, thin, gray veil of mist and as it descended the water from the Sound began to rise. I watched it carefully and should say it was over 300 and nearer 500 feet high, and in comparison with the measurement of schooners lying near it, it certainly could not have been less than 125 feet in diameter".

Mr. John B. Garrett saw it from Falmouth Heights in an east-southeast direction, and its distance was estimated to be from six to ten miles. He says: "In form it was much like a short section of rubber pipe, flexible, and of the color of a heavy watery cloud. It was telescopic, the upper end of the column vanishing in the small end of a funnel-shaped cloud somewhat larger than itself.

"Shortly before it broke and disappeared, the main column drew upward, disclosing at its lower end a smaller column or tube within the main one. There was also visible for a time, as it broke, a distinct spiral and rotary motion, extending about one-third the length of the column from its upper end.

"During the whole appearance the water at its base, considerably wider than the column, was churned into a seething mass and raised to a great height.

"If the estimate of the distance from Falmouth Heights be approximately correct, your previous correspondent's estimate of the diameter of the waterspout, 125 feet, must be within rather than beyond the actual; and, assuming this as correct, the height of the column can not have been less than 750 feet. The height to which the spray was thrown was decidedly greater than the width of the column, and must, therefore, be estimated above 125 feet".

Doctor Abbott estimates the height of the waterspout to have been 3000 or 4000 feet, judging from its appearance above a distant hill, and the "probable distance away of the phenomenon". He says: "From all that I can learn, the waterspout was about 25 miles distant". But it could not have been that distance away from him, and yet have been seen in an "east-southeast" direction from Falmouth Heights, and in a "northerly" direction from Vineyard Haven. Still from his point of view, at ten miles distance, it must have been over 1000 feet in height. He writes that "the waterspout was soon followed by marked atmospheric disturbances. Thunder, lightning, hail, and rain in abundance fell within an hour or more. A dense, dark cloud formed in the northwest, followed by a squall from the southwest, and the wind shifted in a short time from northeast to southeast, and then by southwest to northwest. The thermometer at 2:00 p. m. indicated 56°, a very low reading for a place where it has varied but little from 70° all summer".

(I) COPY OF LETTER OF REV. CRANDALL J. NORTH, OF NEW HAVEN, CONN., IN THE CHRISTIAN ADVOCATE FOR SEPTEMBER 24, 1896.

Thousands of summer residents of Marthas Vineyard, Nantucket, and the adjacent Massachusetts coast were treated to a spectacle of remarkable grandeur one day in August, last. Guests at the hotels and occupants of cottages at the various resorts were just rising from dinner when the cry was raised, "A waterspout, a waterspout!" The scene presented to view was such as not one in a thousand had ever witnessed before or would ever see again.

A large mass of heavy black cloud hung high above the ocean between Nantucket and Cape Cod. Suddenly it was seen to project a circular column of its own dense vapor perpendicularly downward, rapidly but not precipitantly, until sea and cloud were connected by a cylinder one or two hundred feet in diameter, straight as a pine tree, and at least a mile high. It was a waterspout indeed, of most unusual proportions and indescribable beauty.

The sea was perfectly calm, the air almost motionless, the sun shining brightly, light summer clouds hanging here and there over the deep blue sky; and in strange contrast with all the rest, was this lofty mass of black vapor with its absolutely perpendicular support. To add to the weird effect occasional livid streaks of forked lightning shot athwart the black monster cloud above. The column was only slightly funnel-shaped just where it joined the cloud, and was of equal diameter the remainder of its length. At its base the sea was lashed into a mass of white foam and spray that mounted upward as high as the masts of a large schooner.

From Cottage City it seemed about six miles distant, but careful observation through a glass from the writer's view-point showed that it was nearly in line with the light-ship off Hyannis Harbor, and still farther distant, its foot resting upon the sea beyond the horizon line. It must have been twenty or twenty-five miles away, but such was its magnitude that it seemed not more than one quarter of that distance.

It moved slowly eastward, and continued with little change in form for seventeen minutes. Then it gradually attenuated till it looked like a dark ribbon hanging out of the cloud, and at length disappeared. The lashing of the water into foam and spray where its base had rested continued unabated, which was evidence that the waterspout was still there, though now invisible, and that it might be expected to reappear. Surely enough, after an interval of about ten minutes, the cylindrical form of black vapor began to push its way downward again from the cloud and continued until it stood again upon the white mass of foam and spray mounting up from the sea surface. This time its top was more funnel-shaped and curved to the eastward. It continued eight minutes and disappeared. The projecting of the visible vapor downward caused the illusion that its origin was from the cloud rather than from the sea, and many supposed that it was a cloud-burst rather than a waterspout; but this is disproved by the continuance of the agitation of the sea surface during the interval between the disappearance of the first column of visible vapor and the formation of the second. Also the descent of the column was too slow for a mass of water falling from a cloud-burst, as was clearly apparent a little later, when a real cloud-burst occurred upon the mainland opposite, in full view from our point of observation.

The apparent formation from top downward was due to the fact that the atmosphere became more rarefied by the swifter gyrations of the whirlwind at the higher altitude, causing the invisible vapor carried up from the sea surface to condense and become visible at the highest level first; then its visibility gradually extended downward as the velocity of the gyrations below increased. The whirlwind lashed the sea into foam and spray and vapor, and stood it up in an invisible column; but it turned into cloud at the top first, then downward its entire length, until there it stood for many minutes before the wondering gaze of thousands, a veritable "pillar of cloud by day".

The old sea captains of Marthas Vineyard said that this waterspout exceeded in size and grandeur anything of the kind they had seen during all of their seafaring experience. Enterprising photographers secured several good photographs of the remarkable phenomenon.

(J) COPY OF DESCRIPTION BY DR. F. C. V. H. VOM SAAL; APPARENTLY COMPILED FROM OBSERVATIONS AT COTTAGE CITY, AND PUBLISHED IN THE SCIENTIFIC AMERICAN, NEW YORK, SEPTEMBER 26, 1896.

About 12:30 p. m., August 19, 1896, one of the very dark clouds hovering over Vineyard Sound, between the mainland and Cottage City, was seen to send out a downward and sharply pointed streak of cloud matter, whose funnel-shaped basis above was not at all times visible. After a duration of about fifteen minutes it broke and completely vanished. The apparition quickly emptied of their summer residents all the cottages along the Sound and adjacent islands, Nantucket included. No photographs were taken of this first spout, to my knowledge.

Shortly afterward a long tongue emanated from the same clouds, and was slowly pushed downward to a point about 100 feet from the surface of the ocean. Its height was certainly a mile, and the band-like shape gradually increased in width. With a glass, slow gyratory movements could be detected, also longitudinal stripes caused by falling water. This cloud-burst[4] made the water below, over a surface of many hundred yards, look like a boiling pool. The jumping spray from this was also caught and drawn upward into the whirl toward the downpouring column. This latter, now of lighter color, being struck by the sun, was gradually withdrawn upward, evidently thinning and broadening toward its base. With a glass, mists could still be seen falling into the snow-white foaming area below. The duration of this second and most perfect phenomenon of the day—there were three in all—was about half an hour.

About twenty minutes after its disappearance a third began to form, gradually coming downward from the same clouds, though from a spot a little farther north; but it hardly reached completion. It is very important to note that, in this third case, the ocean below was entirely quiet for a time, being only disturbed later on, when the same process of condensation, mentioned above, caused a similar downpouring, especially noticeable in the period of retraction. It was soon apparent that the agency causing the spouts had spent its energy; the column was evidently thinner in substance and its formation slower and hesitating. It stopped midway, sending only an attenuated end farther, to be withdrawn upward soon after.

During almost all of the time since the appearance of the first spout there was a heavy rainstorm accompanied by flashes of lightning from the northern and darkest portion of the long motionless stratum of clouds above mentioned.

Cottage City, which had been in sunshine until then, was visited by a drenching rain some hours later.

The long duration of the phenomena just described enabled the writer to form a somewhat different opinion of the nature of such waterspouts from what is commonly held. True, I must fall back upon the old (or rather older) explanation, that such whirls are caused by two winds striking each other at an obtuse angle. The greatest rotary velocity must be placed at the spot, about 100 feet above the ocean, toward which the cloud matter from above and the spray from below were drawn. As condensation was continually transforming this cloud matter into water, it stands to reason that by far greater quantities of it were drawn down than was apparent to the eye.

But the spout is from above and not from below, as a glance at the cut conclusively proves. This also definitely settles the question as to what part the ocean takes in the constitution of the column, which is practically none. The "boiling as if in a caldron" is not caused by the action of the circling wind, but by the great quantities of falling water. Nor is there a whirlpool action in, nor rising from, the body proper of the ocean. The way the spray, caught and drawn up, looked at times, easily explained to me how this delusion originated.

The surprising tranquility of the clouds shows that such currents of wind need not be of great height, at least not at their borders, where alone such whirls can take place. That the spouts scarcely shifted their position is proof that the velocity of the concurrent winds was almost equal. It is certain that this velocity can not have been great. Several small vessels in close proximity at the time report that there were a great noise and gusts of wind in the immediate vicinity of the display, while beyond this there was almost a dead calm (Boston Globe, September 1). This latter statement, however, seems to be somewhat exaggerated.

THE PHOTOGRAPHS.

We have to acknowledge our debt to the photographers who happened to be in the neighborhood of Cottage City on August 19, 1896, for an admirable series of pictures which cover the most important features of the phenomenon. Messrs. Baldwin Coolidge, 146 Tremont street, Boston, Mass; J. N. Chamberlain, Cottage City; F. W. Ward, 16 Adams street, Burlington, Vt.; Dodge, of Bangor, Me.; and E. K. Hallet, through Mr. Coolidge have placed their photographs in the care of the Weather Bureau for study, and our thanks are hereby extended to these gentlemen for their courteous contributions to the available scientific data that have come into our possession. Both Coolidge and Chamberlain were stationed on the bluff at Cottage City, and had a clear view over the ocean to the waterspout; Mr. Ward stood near the foot of Hope avenue, in Falmouth Heights; Mr. Dodge was at the head of Vineyard Haven Harbor and saw the spout across the headland near East Chop light; Mr. Hallet was on the high ground west of Cottage City. These locations are shown on the chart, fig. 25. Some other photographs were taken on a small scale which contributed somewhat to the information contained in those reproduced in this memoir.

The first appearance of a waterspout began at 12:45 p. m. and ended at 12:58 p. m.; no photographs were made of this phenomenon, as it required time to bring the cameras into operation. Mr. Coolidge was half a mile away from his studio, at home for dinner, when this spout appeared; he started to secure his instrument, when unfortunately the spout disappeared. He was ready on the bluff for the second appearance, which began at 1:00 p. m. and ended at 1:18 p. m. He used a rapid symmetrical Ross lens, with a focal length $14\frac{5}{8}$ inches from the diaphragm to the ground glass, or $13\frac{1}{2}$ inches from the back of the lens to the ground glass. Mr. Chamberlain brought his camera from his studio to the edge of the park, about 200 yards from the water, and his pictures, therefore, include a foreground showing several telegraph poles. The measured distances between these objects give the scale of the photograph, which becomes more valuable on this account. He used a large camera, No. 5 euroscope, with equivalent focus of $17\frac{1}{2}$ inches from the optical center to the sensitive plate, and a lens of $3\frac{1}{8}$ inches diameter. These sets of photographs by Coolidge and Chamberlain both show a schooner which was sailing southeastward, and the positions of the schooner relative to the waterspout in its successive positions are very useful in determining the time intervals between the successive pictures. One of Chamberlain's, fig. 27, also shows the Succonesset Shoal light-ship, together with the waterspout near it, and this is important in identifying the direction of the sight lines from Cottage City. Mr. Ward's picture was taken with an Anthony kodak triad camera, $4\frac{1}{2}$ inches focal length, and the plate is 4 by 5 inches; this was enlarged by Coolidge to the 8 by 10 size. It shows the cloud formation and is most instructive as to general meteorological conditions; it also shows the curvature of the vortex tube at right angles to the view from Cottage City, where it seemed nearly straight, as seen in perspective during the second appearance. Mr. Dodge caught a distant view of the spout, and his picture also shows the great cumulo-nimbus cloud from which it descended; his sight line passed just to the south of the East Chop lighthouse, and this distinctly identifies the direction of the spout at that time. Hallet's picture was taken with a small camera, but shows the large cumulo-nimbus cloud so well that I have taken it as the basis of the thermodynamic computations.

The following is a list of the photographs and the times when they were taken:

SECOND APPEARANCE.

Fig. No.	Serial No. of photograph.	Phase.	Photographer.	Moment of exposure.	Photographer's numeration of negative.
27	1	2d A	Chamberlain	1:02 p. m.	
28	2	2d B	Coolidge	1:03 p. m.	7933
29	3	2d C	Hallet	1:08 p. m.	
30	4	2d D	Dodge	1:12 p. m.	
31	5	2d E	Ward	1:14 p. m.	
32	6	2d F	Coolidge	1:15 p. m.	7934
33	7	2d G	Coolidge	1:17 p. m.	7936

THIRD APPEARANCE.

34	8	3d A	Chamberlain	1:20 p. m.	
35	9	3d B	Chamberlain	1:24 p. m.	
36	10	3d C	Coolidge	1:27 p. m.	7935

[4] Of course this was not the "cloud-burst" of technical meteorology, for that is simply an unusual excessive rainfall.—EDITOR.

Notes on the photographs.

No. 1. See fig. 27.—*Chamberlain, 2d A,* at 1:02 p. m., showing the waterspout 5.75 miles away, the lower face of the cloud in great detail, the foreground, the schooner about two miles out, and Succonesset Shoal light-ship about eight miles distant; the latter can be seen on the horizon about one third of the apparent distance from the spout to the schooner.

No. 2. See fig. 28.—*Coolidge, 2d B,* at 1:03 p. m., includes the Marthas Vineyard steamer, the spout and cloud in nearly the same condition as shown by 2d A.

No. 3. See fig. 29.—*Hallet–Coolidge, 2d C,* at 1:08 p. m. This picture is attributed to E. K. Hallet, photographer, and is copyrighted by Baldwin Coolidge, Boston, Mass., 1897. It seems to be somewhat later than 2d B because the vortex is leaning more toward the south, in accordance with the drift of the cloud stratum, which is brought out more positively in the third appearance, 1:20 to 1:25 p. m.; it also gives us the dimension of the upper cloud which is not seen in the pictures 2d A, 2d B. Such small-scale photographs of the whole cloud region serve admirably to supplement the details to be found only on the large-scale pictures, and should always be made if possible by those having kodaks at hand.

No. 4. See fig. 30.—*Dodge, 2d D,* at 1:12 p. m., is chiefly of importance in locating the line from the head of Vineyard Haven Harbor to the waterspout. The curvature toward the southwest in the center begins to be seen from that angle I estimate that this was taken at 1:12 p. m., though there may be some doubt about the exact minute.

No. 5. See fig. 31.—*Ward–Coolidge, 2d E,* probably at 1:14 p. m., taken by F. W. Ward, enlarged and copyrighted by Baldwin Coolidge. The curvature of the tube is now fully seen from Falmouth Heights, where this plate was taken, this sight line being nearly at right angles to those from Cottage City. The vortex column appeared vertical at Cottage City, but strongly curved at Falmouth Heights with convexity toward the southwest. In the third appearance the convexity is seen nearly broadside on at Cottage City, and this indicates some change in the drift of the lower surface of the cloud relative to the layer of air at the water. This photograph gives the horizontal extent of the cloud. The Hallet photograph, fig. 29, 2d C, shows the precipitation in the thunderstorm preceding the waterspout by about one mile.

No. 6. See fig. 32.—*Coolidge, 2d F,* at 1:15 p. m., shows the enlargement of the tube before breaking up, the spray being cast out from all parts of the tube, especially at the top, thus causing the conical form.

No. 7. See fig. 33.—*Coolidge, 2d G,* at 1:17 p. m., gives the phenomenon at the breaking up of the second appearance, and it locates the schooner well up to the place of the vortex.

There are three photographs of the third appearance.

No. 8. See fig. 34.—*Chamberlain, 3d A,* at 1:20 p. m., shows the top of the vortex advanced toward the south relative to the base, indicating the drift in the cloud stratum. The schooner has moved beyond the base of the waterspout and is between the two telegraph poles; a tow of barges is just coming into view on the extreme right of the photograph.

No. 9. See fig. 35.—*Chamberlain, 3d B,* at 1:24 p. m., is similar to the preceding, but the base of the spout has moved toward the southeast; the schooner and the barges are approaching each other.

No. 10. See fig. 36.—*Coolidge, 3d C,* at 1:27 p. m., is a later phase of the third appearance, with the schooner and head of the tow nearly in the same line. The schooner is about two and one-half and the barges about three miles distant from Cottage City.

POSITION OF THE WATERSPOUT IN THE SOUND.

It will be seen that from the foregoing notes, the photographs, and the chart we have considerable data with which to find the position of the waterspout in Vineyard Sound. It will be best first to fix our attention upon the first part of the second appearance as shown in the photograph, Chamberlain, 2d A, fig. 27, taken at about 1:02 p. m. My own personal survey of the ground gives the following distances approximately, as plotted in fig. 26. The telegraph poles are marked 1, 2, 3, 4, and Chamberlain's camera is marked 5. We have the distances, 5–1=450 feet, 5–4=504 feet, 1–2=72 feet, 2–3=120 feet, 3–4=66 feet, 4–1 = 132 feet. The sight line to the waterspout is laid down, also that to the schooner; the angular distance between them is 5.44°. On photograph, Chamberlain, 2d A, fig 27, is also shown the Succonesset Shoal light-ship, which appears as a dot on the horizon about one-third the distance from the foot of the spout to the schooner. This enables us to orient the entire drawing with great accuracy. These lines are now transferred to the chart of Vineyard Sound, published by the U. S. Coast and Geodetic Survey as No. 112, August 1901, of which a portion is reproduced as fig. 25.

On photograph, Dodge, 2d D, fig. 30, taken from the head of Vineyard Haven Harbor, the spout is shown just to the south of East Chop light-house, and that line is added to the chart. The spout was also seen from Woods Hole at the head of Little Harbor, and a measurement of the line as described gives magnetic declination S. 75° E., which is also drawn. It was seen from Edgartown, 10° east of true north, by one report, this line being indicated on the chart, fig. 25.

Dr. George Faulkner's family saw the second appearance from their residence near the water in the town of Falmouth, and their sight line passed just south of the steamboat wharf at Falmouth Heights. This enables us to fix another line as shown on the chart. These lines all converge quite accurately to a point a little south of east of L'Hommedieu Shoal, where other observers also placed it by estimate, and I have accordingly cut off the Chamberlain line of sight at that point on my chart, fig. 25. This makes the distance from Chamberlain to the waterspout 5.75 miles, and to the Succonesset Shoal light-ship eight miles; as the schooner was in the usual inside channel it was about two miles distant, as shown on this same chart. It is instructive to note that some spectators imagined the spout to have been more than twenty miles from Cottage City. It is of great importance to be able to accurately convert the distances shown on the photographs into angles, because the angles, combined with the length of the sight line, give the corresponding linear dimensions at the spout and at the schooner. We have to measure the linear distance on this photograph from the middle of the schooner to the middle of the waterspout, which is 48 millimeters on fig. 27, Chamberlain, 2d A; at the same time the angular distance between the sight lines from the camera to these two objects is found from the survey to be 5.44°. This was determined by plotting the lines of the survey on a large scale, and testing the result by numerous checks on the other distances measured on the photographs. Hence, 1 millimeter = 6′ 48″ of angle. This is the fundamental dimension, and it leads to 1 millimeter = 60 feet = 18.3 meters at the waterspout.

DIMENSIONS AS MEASURED ON PHOTOGRAPH 2D A, FIG. 27.

By this process we obtain the absolute dimensions given in the accompanying table.

	Feet.	Meters.
At the distance 500 feet, 1 mm. is equivalent to	0.989	0.3014
At the distance of 1 mile, 1 mm. is equivalent to	10.444	3.1833
At the distance of the schooner, 1 mm. is equivalent to	20.888	6.3667
At the distance of the waterspout, 1 mm. is equivalent to	60.00	18.288
Length of schooner hull (3 mm.)	62.7	19.111
Length of schooner over all (4 mm.)	83.6	25.481
Diameter of the waterspout at the water (4 mm.)	240	73.15
Diameter of the foot of the cascade (12 mm.)	720	219.46
Height of the cascade (7 mm.)	420	128.02
Diameter of the vortex tube at middle (2.4 mm.)	144	43.89
Diameter just at face of the cloud (14 mm.)	840	256.03
Approximate length of the tube (60 mm.)	3600	1097.3
Approximate height of the top of the cloud (from 2d C, fig. 29)	16000	4876.8

Distance from middle of schooner to middle of waterspout on the horizon, measured on the photograph, 48 mm.

Angular distance subtended by the sight lines at the camera, as determined by the local survey, 5.44°.

Hence, 1 mm. subtends $5.44° \div 48 = 0.1133° = 6.80' = 6'48''$.

The distance moved by the waterspout from the beginning of the first appearance at 12:45 p. m. to the end of the third appearance at 1:28 p. m. can be found as follows:

The positions of the schooner and the waterspout at the time of taking Chamberlain's three photographs are shown on the chart (see fig. 25), as nearly as can be determined; 2d A, at 1:02 p. m.; 3d A, at 1:20 p. m.; 3d B, at 1:24 p. m. In the interval, 1:02 to 1:24 p. m., 22 minutes, the schooner moved about 0.65 mile. This is at the rate of 1.7 miles per hour. The schooner was sailing nearly east-southeast, and the sails were set to catch a wind from the northwest. The wind was very light at the time, as stated by several observers, and as is shown on the photographs by the smoothness of the water. In the interval, 12:45 to 1:28 p. m., 43 minutes, the vessel passed over the distance 1.27 miles. Similarly, the waterspout passed over the distance 0.4 mile in the interval, 1:02 to 1:24 p. m., and over the distance 0.78 mile, or 4018 feet, in the interval, 12:45 to 1:28 p. m., while the whole phenomenon was in evidence. This is at the rate of 1.10 miles per hour.

It is instructive to compare these results with the estimated dimensions and distances as reported by different spectators. Mr. Hanes estimated the eastward progress as 2 miles, diameter from 100 to 300 feet, height 4000 to 5000 feet. Mr. North made the distance of the waterspout from Cottage City 20 miles, or more, supposing that the foot of the vortex was beyond the horizon, and that from his view-point the base of the tube was 20 feet above the sea level; he made its eastward movement about equal to its own height before it disappeared, which is nearly correct, and called this one mile. Mr. Coolidge, October 19, 1896, estimated the height of the spout at from 6000 to 10,000 feet, or 21 to 28 times its diameter, and the latter at 300 to 375 feet and the distance 8 miles. Mr. Coolidge, September 1, 1897, made it 400 to 600 feet in diameter at its mid-height, from 4000 to 6000 feet, or perhaps 10,000 feet high, and 5 miles distant. The observers on the yacht *Avalon*, which was very near the waterspout, made the diameter 100 feet. Mr. E. H. Garrett estimated over 300 to nearly 500 feet high, and 125 feet in diameter; Mr. John B. Garrett; 6 miles distant, height, 750 feet; diameter, 125 feet; height of cascade, 125 feet; Mr. Abbott; height, 3000 to 4000 feet.

[The treatment of this waterspout will be continued in Sections VII, VIII, and IX.]

CLIMATOLOGY OF PORTO RICO FROM 1867 TO 1905, INCLUSIVE.

By Mr. WILLIAM H. ALEXANDER, Observer, Weather Bureau. Dated Burlington, Vt., April 23, 1906.

OROGRAPHY AND TOPOGRAPHY.

On pages 522–523 of the MONTHLY WEATHER REVIEW for November, 1902, under the heading "The Climatology and Water Power of Porto Rico", may be found a few appropriate remarks introductory to this discussion, particularly as regards the topography of the island. Subsequent to the date of that paper the following places of interest were visited for the purpose of securing additional data: Rio Piedras, Caguas, San Lorenzo, Cidra, Cayey, Aibonito, Coamo, Barranquitas, Barros, Comerio, Bayamon, Carolina, Canóvanas, Fajardo, Hacienda Perla, Manati, Ciales, La Isolina, Morovis, El Yunque, Camuy, Quebradillas, Isabela, Aguadilla, Hacienda Coloso, Aguada (the reputed landing place of Columbus in 1493), Añasco, Mayagüez, Las Marias, Cabo Rojo, San German, Lajas, Hacienda Amistad, Guanica (the landing place of General Miles in 1898), Yauco, Ponce, La Carmelita, Adjuntas, San Salvador, Utuado, and Arecibo. The information thus gained seems to warrant a few additional observations relative to the physical features of the island. (See Chart VII.)

In the first place, careful barometric (aneroid) readings made during the journey to the summit of El Yunque (universally regarded as the highest point on the island) seem to indicate beyond a doubt that the true elevation of that mountain is not more than 3300 feet, instead of 6000 as frequently stated in old records. Again, just north of Ponce in the vicinity of La Carmelita, the same barometer gave as the correct elevation of the dividing ridge 2428 feet. It seems proper, therefore, to amend a former statement to the effect that "the dividing ridge varies in height from 2500 to 3670 feet" so as to make the variation from about 2000 to 3300 feet. This dividing ridge from El Yunque to Humacao is known as "Sierra de Luquillo"; from Humacao to Aibonito, "Sierra de Cayey"; and from Aibonito westward, "Cordillera Central". The two most important depressions in this divide are where the San Juan-Ponce Military Road crosses it, between Aibonito and Coamo, and where the Ponce–Arecibo Road crosses, just south of Adjuntas. Just west of Adjuntas there is an abrupt rise in the range second in importance only to El Yunque. The central figure in this group is known as Mount Guilarte which is very nearly as high as El Yunque. This is the true culminating point to the westward, and from a topographic point of view is the dominating factor in the climatology of the west end of the island. From Mount Guilarte a number of rugged spurs or dividing ridges branch off; one toward the northwest corner of the island; one toward the southwest, terminating near Cabo Rojo; and one between these in the direction of the little village of Rincon.

As to the secondary topographic features of the island, no better description, perhaps, can be given than that of Mr. Herbert M. Wilson in Irrigation Paper No. 32, U. S. Geological Survey, page 14. He says:

> Abutting against the foothills of the commanding sierras, and forming secondary topographic features of striking importance, are a number of varied forms found at different portions of the island, and owing their shape and mode of weathering to their geologic origin. On the north coast, between Arecibo, San Juan, and Fajardo, the main summits fall away rather abruptly to elevations of between 1000 and 1500 feet; they then continue as radial spurs, sloping gently to the northward and interrupted by numerous undulations, culminating often in peaks of considerable altitude and prominence.
>
> These are separated by the principal rivers draining the interior, which flow generally to the north, but are deeply indented in the surface of the country. Thus, within five or six miles to the north of the main summits the river bottoms are at altitudes of about 1000 feet, while the summits of the ridges above are at elevations of 2000 to 2500 feet. Again, within five miles of the coast the river beds are at elevations of 50 to 100 feet above sea level, while the summits of the dividing ridges reach altitudes of 1000 to 1500 feet. These dividing ridges are often maintained to the ocean shore, are high, narrow, and A-shaped, and are separated from one another by deep V-shaped valleys, eroded by numerous streams flowing in every direction throughout the interior of the island.

The coastal topography is more simple and consists in the main of playas, or level plains, that in places extend some five or six miles up the river valleys. The playas do not extend in unbroken continuity around the island, but are interrupted in several places. For instance, at the northeast corner of the island spurs from the Sierro de Luquillo plunge directly into the sea; on the northwest corner there is a coral plateau extending from Arecibo to Aguadilla that juts right out to sea. The south and southwest coasts are peculiar in that the playas are separated from the sea by low-lying limestone hills, which are more pronounced along the southwest coast.

From the above, it would seem that waterfalls must of necessity be common in the rivers of the island. There are many falls and some of considerable importance, especially in the Rio de la Plata and the Arecibo. The river channels lend themselves to dam construction so readily as to make this a matter of comparatively small expense. Springs abound in

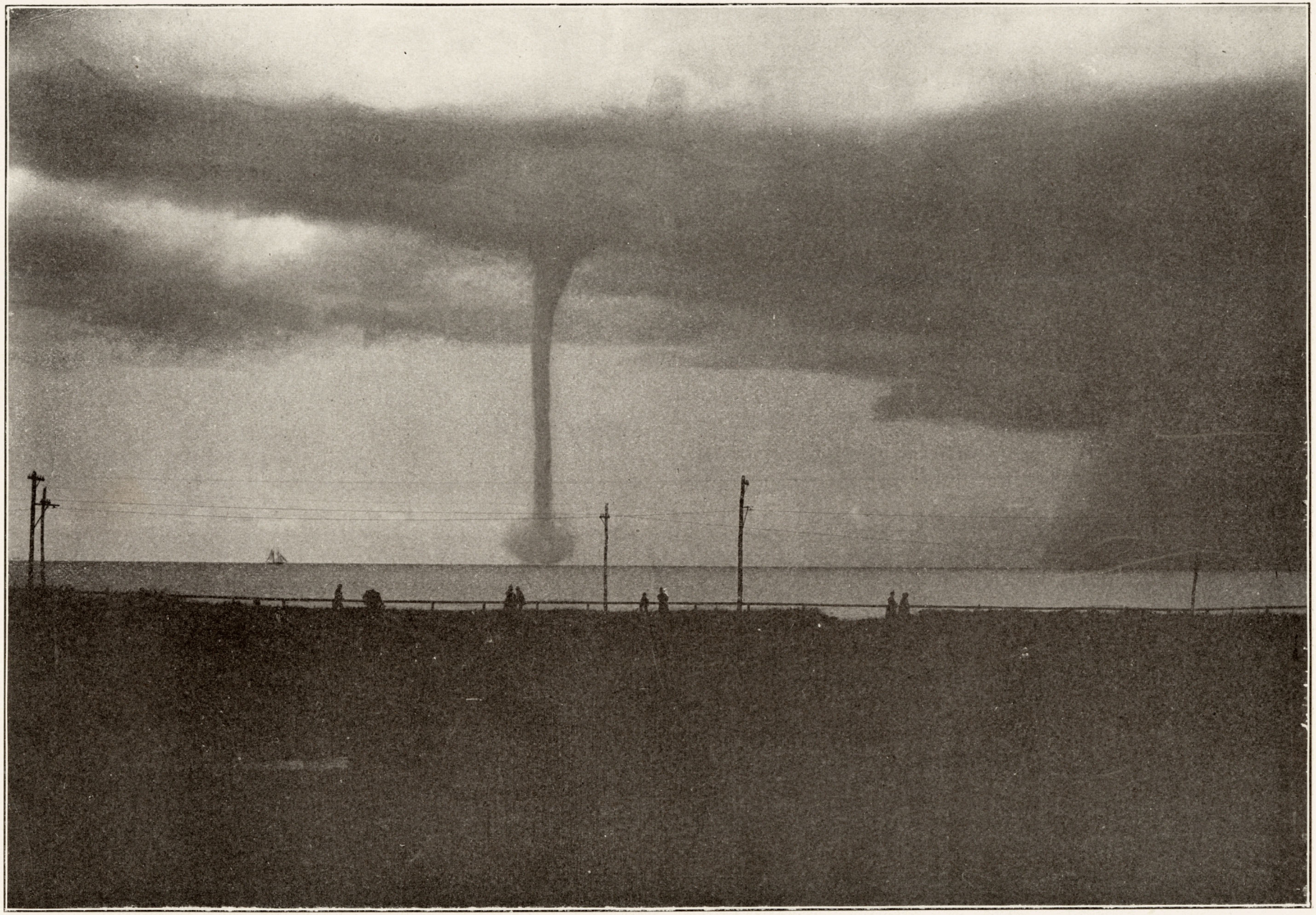

FIG. 27.—2d A; second appearance; Chamberlain; Cottage City; 1:02 p. m.

FIG. 28.—2d B; second appearance; Coolidge; Cottage City; 1.03 p. m.

FIG. 29.—2d C; second appearance; Hallet; Cottage City; 1:08 p. m.

FIG. 30.—2d D; second appearance; Dodge; Vineyard Haven; 1:12 p. m.

FIG. 31.—2d E; second appearance; Ward; Falmouth Heights; 1:14 p. m.

FIG. 32.—2d F; second appearance; Coolidge; Cottage City; 1:15 p. m.

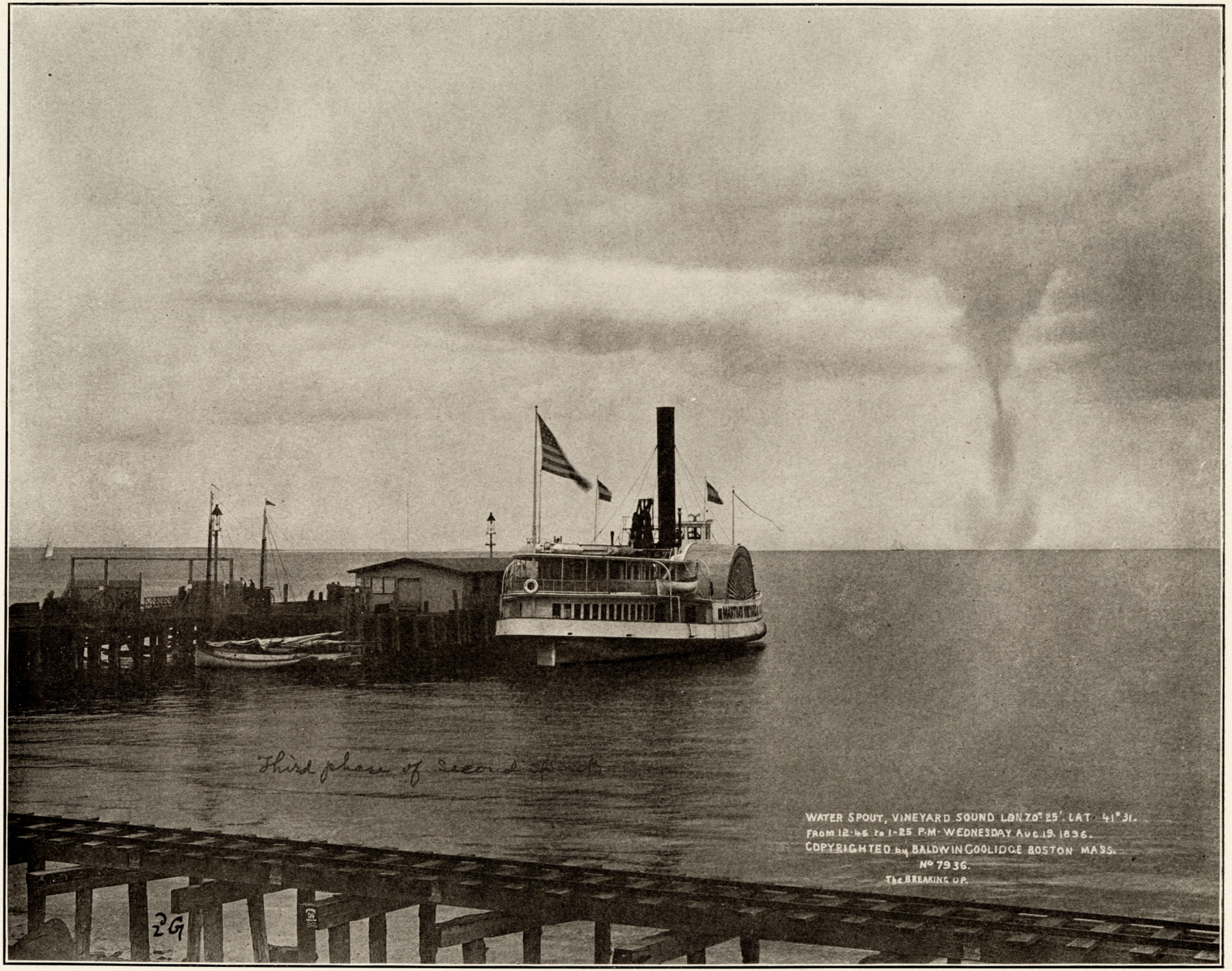

FIG. 33.—2d G; second appearance; Coolidge; Cottage City; 1:17 p. m.

FIG. 34.—3d A; third appearance; Chamberlain; Cottage City; 1:20 p. m.

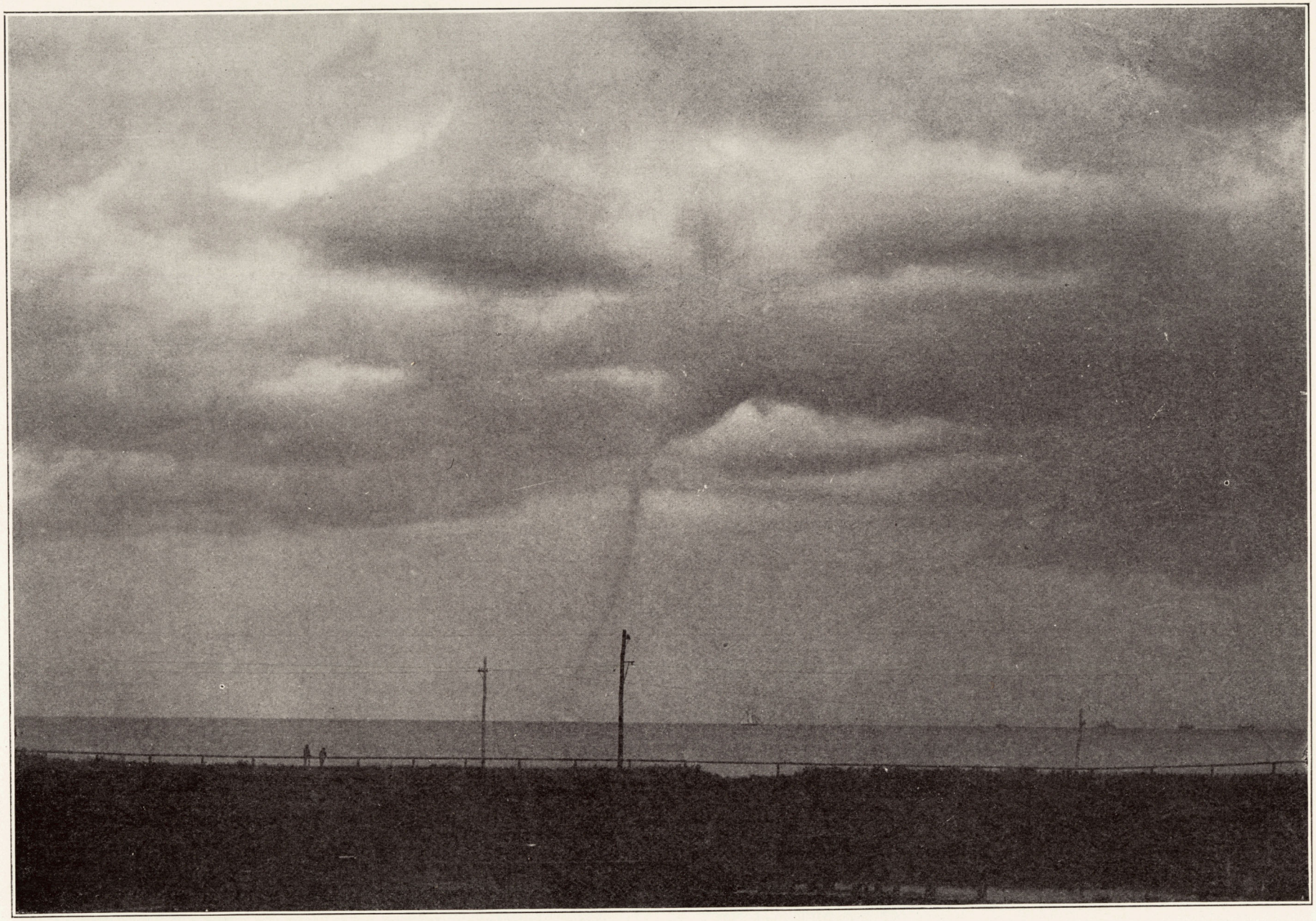

FIG. 35.—3d B; third appearance; Chamberlain; Cottage City; 1:24 p. m.

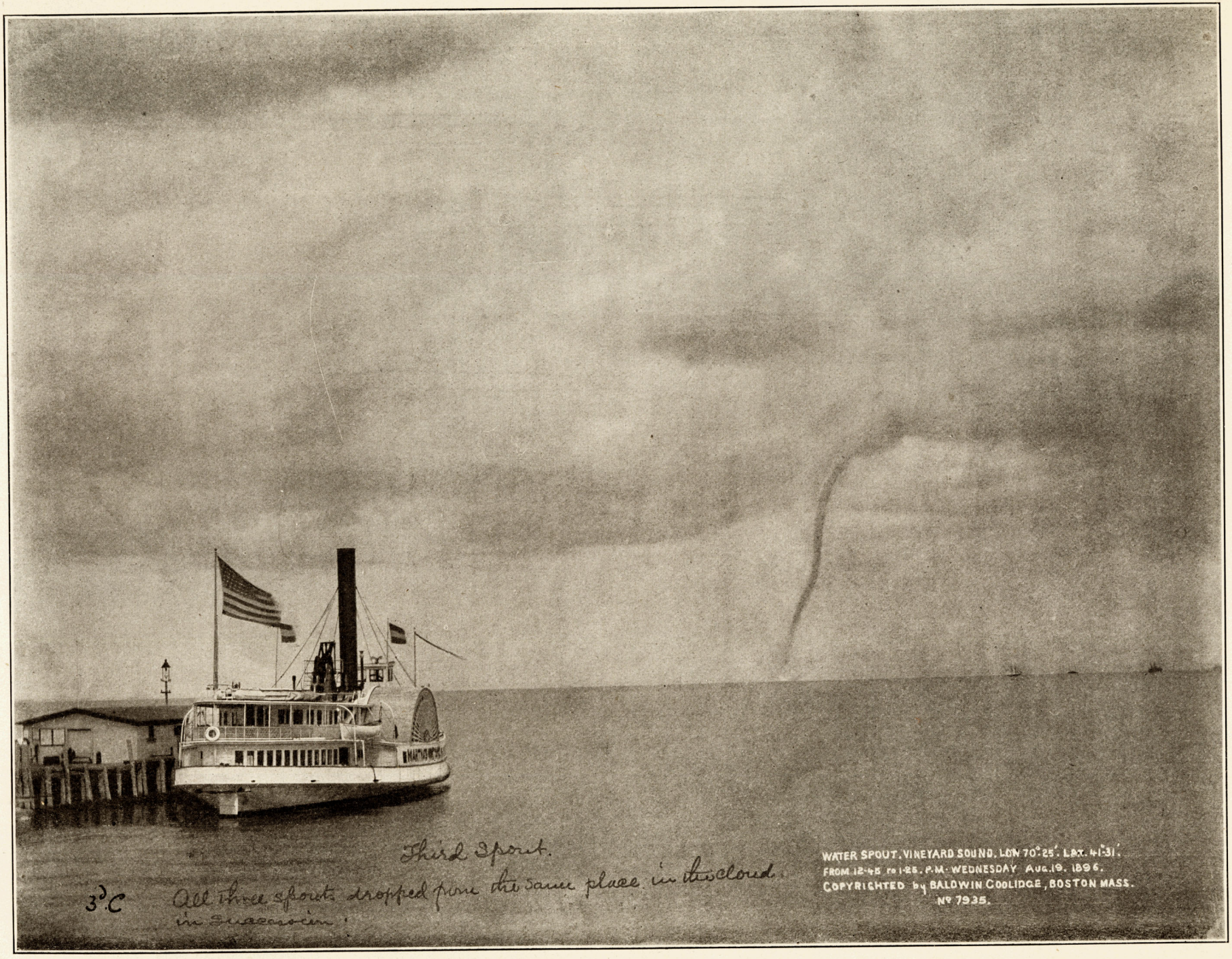

FIG. 36.—3d C; third appearance; Coolidge; Cottage City; 1:27 p. m.